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PRIMARY LEVEL ULTRASONIC OUTPUT POWER MEASUREMENT AT LABORATORY OF ULTRASOUND OF INMETRO

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Abstract: The primary level ultrasonic output power measurement service is being set up at the Laboratory of Ultrasound (Labus) of Inmetro, based on the standard IEC 61161. Labus´ main purpose is to provide support, in accordance with procedures developed by its services, to industry, to calibration laboratories, and to final consumers (patients, for instance). Labus' clients will have means and necessary data to obtain, between other things, pre-market approvals of new models or equipment, laboratory accreditation, and on demand checks of equipment already being in use. These procedures will ensure optimized and safe use of ultrasound technology at all levels. This paper presents the main characteristics of Labus' primary level ultrasonic output power measurement service.

Keywords: ultrasound, metrology, ultrasound output power, radiation force balance.

1. INTRODUCTION

Traceable ultrasound power measurement aims quality and safety issues other than just ultrasound system characterization. Those items are of great importance, especially regarding high ultrasound output power applications and even more where human beings are the object of those applications. In this case, there is an interest in getting the best cost-benefit relationship, i.e., a patient, once being exposed to a technology of risk, the received benefits are higher than the deleterious effects that technology could cause, to him, during treatment (Principle ALARA – As Low As Reasonably Achievable) [1].

2. STANDARD IEC 61.161 – RELEVANT ASPECTS

Most of the primary level ultrasound laboratories around the world have the Standard IEC 61.161 – *Ultrasonic Power Measurement in Liquids in the Frequency Range 0,5 MHz to 25 MHz,* as reference on their calibration procedures. IEC 61.161 was first published in 1992 and revised in 1998. That standard provides the basic characteristics of a radiation force balance in order to measure the ultrasound power output.

2.1. Radiation force balance with reflecting target

In radiation force balances with reflecting target, the interaction between the ultrasonic beam and the target is mainly due to the reflection phenomenon. In accordance to [2], cone-shaped targets are the most usual reflectors. They are made of metal-coated stiff foam or air backed metal cone shells. Unfortunately, there is no specification in [2] over the best metal and foam or cone thickness (air backed metal cones) used to manufacture targets.

There are two types of reflecting cone-shaped targets: concave and convex cones. Convex cones are easier to manufacture than concave ones [2]. Convex cones have a half angle of 45°. Under a perfect alignment of the acoustic beam with the target apex (135º), the incident wave is reflected 90° away from the acoustic beam main axis. Concave cones half angle can vary from 60° to 65°. In that case, incident wave is reflected nearer to the transducer face, but does not interfere in the measurement [2].

The target radius *b* should be large enough in order to covered at least 98% (or more) of the acoustic beam, assuming an infinite diameter. As a precaution, *b* should never be less than 1.5×*a*, where *a* is the radius of the transducer active element. A detailed procedure to calculate the minimum value of *b* is given by [2].

For perfect reflecting targets, the ultrasonic output power is given by equation (1):

$$P = \frac{cF}{\left(2\cos^2(\theta)\right)} \qquad (1)$$

where P is the ultrasound output power, c is the sound velocity in water, F is the radiation force and θ is the angle between the incident wave and the normal to the reflecting surface [2].

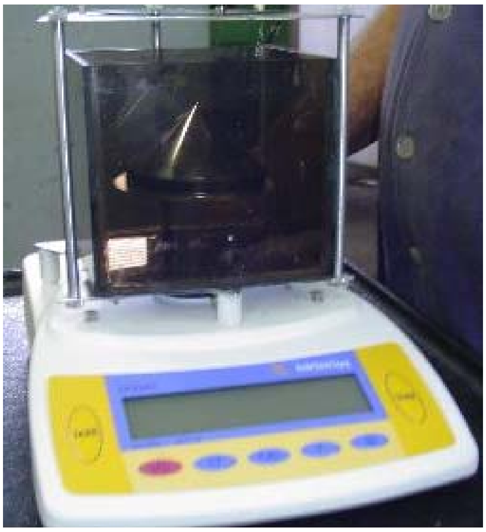
Equation (1) assumes the target is large enough to cover the entire cross section of the acoustic beam so that, the amount of ultrasonic output power that misses the target could be neglected when compared to the total ultrasonic output power [2]. Also, equation (1) is valid for low ultrasonic absorption media and plane waves assumption (far field).

3. MATERIALS AND METHODS

The radiation force balance, as defined by [2], is a gravimetric balance, which means that the beam orientation is vertical, either facing downwards or upwards.

In this work, the radiation force balance consists of a stainless steel cone shaped target (Figure 1a) connected to an analytical balance (Figure 1b) by means of an appropriate structure, manufactured at Inmetro. The ultrasonic beam is directed downwards (Figure 2) on the reflecting target (45° half angle and 2.5 cm of radius) and the radiation force exerted by the ultrasonic beam is measured by the balance in mass units and converted to force units using the appropriate acceleration value due to gravity. Inmetro's setup uses a microbalance model CP224-S (Sartorius, Germany), with 0.1mg of readability and 220 g maximum load capacity.

(a)



(b)

Fig. 1:Inmetro Radiation Force Balance: (a)-Reflecting target; (b) Analytical Balance with structure. Structure and cone target were both manufactured at Inmetro

The tank is filled with degassed water to diminish cavitation probability and its walls and bottom are covered with National Physical Laboratory (NPL) certified absorbing linings so that undesirable reflections can be minimized.

The ultrasonic power is determined in accordance with [2] and using equation (1), in other words, from the difference between the force measured with and without ultrasonic radiation. The sound velocity value, in water, is considered as 1491m/s (23 °C) [2].

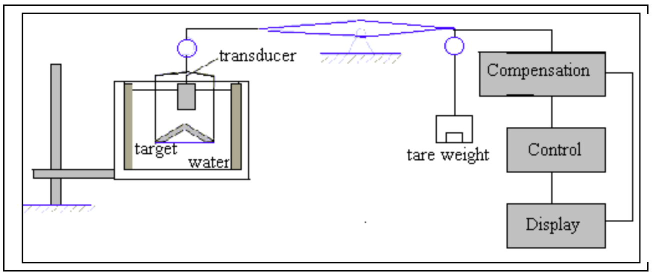


Fig 2:-Schematic diagram of a radiation force balance. Adapted from [3].

Analytical balance calibration will be carried out by means of small precision weights of known mass at the Inmetro Primary Laboratory of Mass (Lamas).

The radiation force balance, presented herein, will be calibrated using a standard check source for 3 nominal power values (10mW, 100mW and 1000mW), with a 3.3 MHz transducer; both traced to the NPL primary standard.

At present time, the whole setup is constantly being improved, so no qualified measurement was obtained using the radiation force balance against the standard check source due the extremely sensible nature of the analytical balance.

4. PRELIMINARY RESULTS

Preliminary results are shown on Table 1. Those results are related to a commercial radiation force balance (Ohmic UPM-DT1) which was traced to this service through the NPL standard check source.

In order to carry out those measurements, a specific procedure was formulated based on general Inmetro´s guidelines. Humidity, atmospheric pressure, and ambient temperature, as well as tank water temperature, were monitored before each measurement set.

The commercial balance to be traced, as well as the NPL standard check source, were both insulated from low frequency mechanical waves (solid and gas vibration).

TABLE 1: Preliminary Results of a Commercial Radiation Force Balance

Nominal Power	10 mW	100mW	1000mW
Number of measurements	4	4	4
Average	10,83	99,16	951.995
Standard Deviation	2,33	2,9	7,7
Type A uncertainty	1,165	1,45	3,85
Type B uncertainty	0,192	2,04	25,75
Combined uncertainty	1,18	2,5	26,03
Expanded uncertainty	2,36	5	52,03
Percentage	21,79%	5,04%	5,46%

The commercial balance, as well as the standard check source, were both set up following manufacturer instructions (operation manual).

Four sets of three measurements, as a function of time (every five seconds), were collected (for each nominal power), being collected, the first data, at 10 seconds, the second at 15 and, the last one at 20 seconds. Following this procedure, the average as a function of time was calculated, so each set gave one result (four sets, four results for every nominal power) which was included directly into the uncertainty calculation.

5. CONCLUSION

It is expected that the primary level ultrasonic output power measurement service will soon be fully functional. Inmetro's Laboratory of Ultrasound will be able to measure ultrasonic output power up to 20 W with resolution of 2mW. This range covers all commercial ultrasound medical equipment (therapy and diagnostic) and the majority of NDE probes. Commercial radiation force balances may be traced to that service through the standard check source as well.

Plans for the future include increasing the service capacity (higher output power measurement range) with better resolutions and lower uncertainties. The primary level ultrasonic output power measurement service is open to whoever is interested in doing research related to ultrasound or applied metrology through agreements between educational institutes at all levels of education.

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